Yield_Curve_Predictor

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0.1 # The Yield Curve as an Accurate Predictor of Economic Crises.

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0.2 Introduction

The Yield Curve, measured as the difference in interest rates between short-term and long-term Treasuries, has long been thought of as a way to determine future economic conditions. More specifically, when the curve inverts (short-term Treasuries yield more than long-term Treasuries), it is interpreted as a sign that an economic recession will soon hit. This project will use data from FRED containing information on the Yield Curve and different economic indicators to gauge whether the Curve has accurately predicted crises.

This project will contain the following three sections:

1. Data on the following economic indicators from January 1982 to April 2019: Civilian Unemployment Rate, Motor Vehicle Retail Sales (Domestic Autos), Industrial Production Index, and the Effective Federal Funds Rate. Here the project will use statistics (e.g. growth rates, normalizing, etc.) on the indicators to find dates when the the indicators reflected recessionary periods.

2. Graphics plotting the four indicators and labels reflecting Yield Curve inversions. Ideally the dates of inversion are soon followed by periods where the economic indicators show an economic decline. This would illustrate that the Yield Curve serves as a predictor of economic crises in the U.S.

3. Five graphics showing normalized numbers as well as difference in numbers for the economic indicators in order to evaluate how they behave following an inversion in the Yield Curve. Each individual graphic will represent the five times it has inverted from 1982 to 2007. Although the Curve did also invert in 2019, I will be excluding this date since the inversion happened late March and there is not much data on the economic indicators thereafter.

0.3 Data Report

As already noted, the data on the Yield Curve and the four economic indicators will be sourced from FRED for a 37 year period. The variables are defined in the following way by FRED:

- Yield Curve: "spread between 10-Year Treasury Constant Maturity and 3-Month Treasury Constant Maturity".

- Civilian Unemployment Rate: "The unemployment rate represents the number of unemployed as a percentage of the labor force. Labor force data are restricted to people 16 years of age and older, who currently reside in 1 of the 50 states or the District of Columbia, who do not reside in institutions (e.g., penal and mental facilities, homes for the aged), and who are not on active duty in the Armed Forces."
- Motor Vehicle Retail Sales (Domestic Autos): "Autos are all passenger cars, including station wagons. Domestic sales are all United States (U.S.) sales of vehicles assembled in the U.S., Canada, and Mexico."
- Industrial Production Index: "The Industrial Production Index (INDPRO) is an economic indicator that measures real output for all facilities located in the United States manufacturing, mining, and electric, and gas utilities (excluding those in U.S. territories)."
- Effective Federal Funds Rate: "The federal funds rate is the interest rate at which depository institutions trade federal funds (balances held at Federal Reserve Banks) with each other overnight."

Now I will run through the process to grab the files using Datareader and create two dataframes: one with the Yield Curve data on it from January 1982 to April 2019 and another with all the economic indicators for the same dates.

Packages Needed

```
In [1]: import pandas as pd

        import matplotlib.pyplot as plt

        import datetime as dt

        import numpy as np

        from pandas_datareader import data
```

Grabbing Data Using Datareader

```
In [2]: codes1 = ["T10Y3M"]

        yield_curve = data.DataReader(codes1, "fred", 1982)

In [3]: codes2 = ["UNRATE", "DAUTOSA", "INDPRO", "FEDFUNDS"]

        economic_indicators = data.DataReader(codes2, "fred", 1982)
```

Renaming For Convenience

```
In [4]: yield_curve.rename(columns = {'T10Y3M': 'Yield'}, inplace = True)
        economic_indicators.rename(columns = {'UNRATE': 'Unemployment_Rate',
                                              'DAUTOSA': 'Vehicle_Sales',
                                             'INDPRO': 'Industrial_Production',
                                             'FEDFUNDS': 'Fed_Funds'}, inplace = True)
```

Dates With Curve Inversion

```
In [5]: yield_curve_inversion = yield_curve.loc[yield_curve['Yield'] < 0]

In [6]: yield_curve_inversion.head()
```

Out[6]:

DATE	Yield
1982-02-01	-0.19
1982-02-02	-0.02
1982-02-08	-0.16
1982-02-10	-0.07
1982-02-11	-0.35

Grouping By Year and Month

```
In [7]: yield_curve_inverted = yield_curve_inversion.groupby(
            [yield_curve_inversion.index.year,
             yield_curve_inversion.index.month])

In [8]: inverted_yield_curve = yield_curve_inverted.agg({"Yield": "mean"})
```

Finalized Dataframes

```
In [9]: inverted_yield_curve
```

Out[9]:

DATE	DATE	Yield
1982	2	-0.357500
1989	3	-0.010000
	5	-0.163333
	6	-0.157273
	7	-0.170625
	8	-0.105625
	10	-0.096667
	11	-0.078947
	12	-0.066875
1998	9	-0.062500
	10	-0.070000
2000	4	-0.045000
	7	-0.121333
	8	-0.451304
	9	-0.376000
	10	-0.556190
	11	-0.639048
	12	-0.696500
2001	1	-0.269231
	2	-0.030000
2006	1	-0.023333

```
           2    -0.038000
           3    -0.010000
           7    -0.058000
           8    -0.213913
           9    -0.211000
           10   -0.317143
           11   -0.478095
           12   -0.408500
      2007 1    -0.345714
           2    -0.440526
           3    -0.515455
           4    -0.312857
           5    -0.143500
           7    -0.088750
           8    -0.110000
      2019 3    -0.038000
           5    -0.030000
```

As we can see above, there were six inversions from 1982 to 2019. However, as mentioned before, 2019's inversion will be excluded. The first inversion of interest ocurred in 1982, the second in 1989, the third in 1998, the fourth in 2000-2001, and the fifth in 2006-2007.

```
In [10]: economic_indicators.head()
```

Out[10]:

DATE	Unemployment_Rate	Vehicle_Sales	Industrial_Production	Fed_Funds
1982-01-01	8.6	445.7	50.3043	13.22
1982-02-01	8.9	520.7	51.3016	14.78
1982-03-01	9.0	489.0	50.9104	14.68
1982-04-01	9.3	455.9	50.4627	14.94
1982-05-01	9.4	531.9	50.1380	14.45

Above, we can see that the monthly numbers for the four economic indicators we are interested in from 1982 to 2019 are found within this dataframe. With it we can perform different analysis/statistics and create visuals.

0.4 Statistics

One useful way to analyze the economic indicators is to view the montly growth rates.

```
In [11]: economic_indicators['UR_Growth_Rate'] = economic_indicators[
             'Unemployment_Rate'].pct_change()
         economic_indicators['VS_Growth_Rate'] = economic_indicators[
             'Vehicle_Sales'].pct_change()
         economic_indicators['IP_Growth_Rate'] = economic_indicators[
             'Industrial_Production'].pct_change()
         economic_indicators['FF_Growth_Rate'] = economic_indicators[
             'Fed_Funds'].pct_change()
```

```
In [12]: economic_indicators.head()
```

Out[12]:

DATE	Unemployment_Rate	Vehicle_Sales	Industrial_Production
1982-01-01	8.6	445.7	50.3043
1982-02-01	8.9	520.7	51.3016
1982-03-01	9.0	489.0	50.9104
1982-04-01	9.3	455.9	50.4627
1982-05-01	9.4	531.9	50.1380

DATE	Fed_Funds	UR_Growth_Rate	VS_Growth_Rate	IP_Growth_Rate
1982-01-01	13.22	NaN	NaN	NaN
1982-02-01	14.78	0.034884	0.168275	0.019825
1982-03-01	14.68	0.011236	-0.060880	-0.007625
1982-04-01	14.94	0.033333	-0.067689	-0.008794
1982-05-01	14.45	0.010753	0.166703	-0.006434

DATE	FF_Growth_Rate
1982-01-01	NaN
1982-02-01	0.118003
1982-03-01	-0.006766
1982-04-01	0.017711
1982-05-01	-0.032798

Before proceeding, it would be good to conduct a preliminary check on the relationship between the Yield Curve and the U.S. economy. To do this, I will create a dataframe which contains only the periods in which the growth rates were positive for the Unemployment Rate, and negative for Vehicle Sales, Industrial Production, and the Effective Fed Funds Rate. It is important to note why for the Unemployment Rate the positive change is what we are after and the negative change for the other three indicators. When the economy faces a crisis, unemployment spikes. Therefore, we care about the dates in which the Unemployment Rate starts growing. For Vehicle Sales and Industrial Production, we are after a negative growth rate because that is when less vehicles and industrial products are made and sold, which happens during an economic decline. For the Fed Funds, we are also after the negative growth number because the Federal Reserve lowers the rate whenever the economy is tanking in an effort to stimulate it.

```
In [13]: negative_impact = economic_indicators.loc[
             (economic_indicators['UR_Growth_Rate'] > 0) &

             (economic_indicators['VS_Growth_Rate'] < 0) &

             (economic_indicators['IP_Growth_Rate'] < 0) &

             (economic_indicators['FF_Growth_Rate'] < 0)]

In [14]: negative_impact
```

Out[14]:

DATE	Unemployment_Rate	Vehicle_Sales	Industrial_Production
1982-03-01	9.0	489.000	50.9104
1982-06-01	9.6	427.500	49.9692
1982-10-01	10.4	444.000	48.7874
1984-10-01	7.4	633.700	55.9459
1986-02-01	7.2	653.000	56.9344
1990-04-01	5.4	572.200	64.2602
1990-11-01	6.2	530.600	63.5753
1991-01-01	6.4	498.400	62.8852
1991-10-01	7.0	501.600	64.0213
1991-12-01	7.3	499.800	63.6937
1995-07-01	5.7	575.300	73.5664
2001-03-01	4.3	523.800	93.7201
2001-04-01	4.4	515.900	93.4469
2001-06-01	4.5	521.700	92.3208
2001-07-01	4.6	486.400	91.7933
2001-08-01	4.9	472.100	91.6795
2001-11-01	5.5	510.600	90.4860
2008-03-01	5.1	395.800	104.4616
2008-11-01	6.8	283.500	96.0605
2009-01-01	7.8	241.700	91.0373
2009-04-01	9.0	251.700	88.3056
2011-04-01	9.1	365.638	96.1187
2015-01-01	5.7	457.731	105.9806
2016-03-01	5.0	426.853	101.4155

DATE	Fed_Funds	UR_Growth_Rate	VS_Growth_Rate	IP_Growth_Rate
1982-03-01	14.68	0.011236	-0.060880	-0.007625
1982-06-01	14.15	0.021277	-0.196277	-0.003367
1982-10-01	9.71	0.029703	-0.138199	-0.008910
1984-10-01	9.99	0.013699	-0.005337	-0.001647
1986-02-01	7.86	0.074627	-0.077944	-0.006561
1990-04-01	8.26	0.038462	-0.002615	-0.001520
1990-11-01	7.81	0.050847	-0.080894	-0.011692
1991-01-01	6.91	0.015873	-0.086510	-0.004341
1991-10-01	5.21	0.014493	-0.029787	-0.001742
1991-12-01	4.43	0.042857	-0.036994	-0.003977
1995-07-01	5.85	0.017857	-0.040687	-0.003978
2001-03-01	5.31	0.023810	-0.086023	-0.002339
2001-04-01	4.80	0.023256	-0.015082	-0.002915
2001-06-01	3.97	0.046512	-0.001913	-0.005978
2001-07-01	3.77	0.022222	-0.067663	-0.005714
2001-08-01	3.65	0.065217	-0.029400	-0.001240
2001-11-01	2.09	0.037736	-0.225072	-0.004899
2008-03-01	2.61	0.040816	-0.032510	-0.002367
2008-11-01	0.39	0.046154	-0.117372	-0.012568

```
2009-01-01       0.15        0.068493       -0.181787       -0.023751
2009-04-01       0.15        0.034483       -0.004745       -0.007981
2011-04-01       0.10        0.011111       -0.013977       -0.003583
2015-01-01       0.11        0.017857       -0.052378       -0.004956
2016-03-01       0.36        0.020408       -0.043608       -0.007895
```

```
            FF_Growth_Rate
DATE
1982-03-01       -0.006766
1982-06-01       -0.020761
1982-10-01       -0.058196
1984-10-01       -0.115929
1986-02-01       -0.034398
1990-04-01       -0.002415
1990-11-01       -0.036991
1991-01-01       -0.054720
1991-10-01       -0.044037
1991-12-01       -0.079002
1995-07-01       -0.025000
2001-03-01       -0.032787
2001-04-01       -0.096045
2001-06-01       -0.057007
2001-07-01       -0.050378
2001-08-01       -0.031830
2001-11-01       -0.160643
2008-03-01       -0.124161
2008-11-01       -0.597938
2009-01-01       -0.062500
2009-04-01       -0.166667
2011-04-01       -0.285714
2015-01-01       -0.083333
2016-03-01       -0.052632
```

As we can see above, the dates roughly follow the inversions. Although it does not give us much, we can see which periods were marked by the most economic decline. Furthermore, we can see that there is not a moment after the 1998 inversion in which the four indicators showed recessionary numbers. This serves as a signal that the inversion of 1998 was probably an outlier.

To further the analysis, it would be appropiate to find the change in the Unemployment Rate and in the Fed Funds rate from the date an inversion first occured. For Vehicle Sales and Industrial Production, we will normalize the numbers from the same dates onwards.

```
In [16]: inversion_1982 = pd.DataFrame()
         inversion_1982['Unemployment_Rate'] = economic_indicators[
             'Unemployment_Rate'] - economic_indicators.loc[
             '1982-02-01,','Unemployment_Rate']
         inversion_1982['Vehicle_Sales'] = economic_indicators[
             'Vehicle_Sales'] / economic_indicators.loc[
             '1982-02-01,','Vehicle_Sales']
```

```
        inversion_1982['Industrial_Production'] = economic_indicators[
            'Industrial_Production'] / economic_indicators.loc[
            '1982-02-01,','Industrial_Production']
        inversion_1982['Fed_Funds'] = economic_indicators[
            'Fed_Funds'] - economic_indicators.loc[
            '1982-02-01,','Fed_Funds']
```

In [17]:
```
        inversion_1989 = pd.DataFrame()
        inversion_1989['Unemployment_Rate'] = economic_indicators[
            'Unemployment_Rate'] - economic_indicators.loc[
            '1989-03-01,','Unemployment_Rate']
        inversion_1989['Vehicle_Sales'] = economic_indicators[
            'Vehicle_Sales'] / economic_indicators.loc[
            '1989-03-01,','Vehicle_Sales']
        inversion_1989['Industrial_Production'] = economic_indicators[
            'Industrial_Production'] / economic_indicators.loc[
            '1989-03-01,','Industrial_Production']
        inversion_1989['Fed_Funds'] = economic_indicators[
            'Fed_Funds'] - economic_indicators.loc[
            '1989-03-01,','Fed_Funds']
```

In [18]:
```
        inversion_1998 = pd.DataFrame()
        inversion_1998['Unemployment_Rate'] = economic_indicators[
            'Unemployment_Rate'] - economic_indicators.loc[
            '1998-09-01,','Unemployment_Rate']
        inversion_1998['Vehicle_Sales'] = economic_indicators[
            'Vehicle_Sales'] / economic_indicators.loc[
            '1998-09-01,','Vehicle_Sales']
        inversion_1998['Industrial_Production'] = economic_indicators[
            'Industrial_Production'] / economic_indicators.loc[
            '1998-09-01,','Industrial_Production']
        inversion_1998['Fed_Funds'] = economic_indicators[
            'Fed_Funds'] - economic_indicators.loc[
            '1998-09-01,','Fed_Funds']
```

In [19]:
```
        inversion_2000 = pd.DataFrame()
        inversion_2000['Unemployment_Rate'] = economic_indicators[
            'Unemployment_Rate'] - economic_indicators.loc[
            '2000-04-01,','Unemployment_Rate']
        inversion_2000['Vehicle_Sales'] = economic_indicators[
            'Vehicle_Sales'] / economic_indicators.loc[
            '2000-04-01,','Vehicle_Sales']
        inversion_2000['Industrial_Production'] = economic_indicators[
            'Industrial_Production'] / economic_indicators.loc[
            '2000-04-01,','Industrial_Production']
        inversion_2000['Fed_Funds'] = economic_indicators[
            'Fed_Funds'] - economic_indicators.loc[
            '2000-04-01,','Fed_Funds']
```

```
In [20]: inversion_2006 = pd.DataFrame()
         inversion_2006['Unemployment_Rate'] = economic_indicators[
             'Unemployment_Rate'] - economic_indicators.loc[
             '2006-01-01,','Unemployment_Rate']
         inversion_2006['Vehicle_Sales'] = economic_indicators[
             'Vehicle_Sales'] / economic_indicators.loc[
             '2006-01-01,','Vehicle_Sales']
         inversion_2006['Industrial_Production'] = economic_indicators[
             'Industrial_Production'] / economic_indicators.loc[
             '2006-01-01,','Industrial_Production']
         inversion_2006['Fed_Funds'] = economic_indicators[
             'Fed_Funds'] - economic_indicators.loc[
             '2006-01-01,','Fed_Funds']
```

Time Delay

Another useful aspect of the data set to look at is how long it took for the four indicators to be negatively impacted since the first date of the Curve's inversion in a given period. This will later be used to plot a bar chart and find the average time the economic decline takes to hit once the Yield Curve has inverted.

```
In [21]: days_1982_inversion = (negative_impact.index[0] - dt.datetime(1982,2,1)).days
         days_1989_inversion = (negative_impact.index[5] - dt.datetime(1989,3,1)).days
         days_2000_inversion = (negative_impact.index[11] - dt.datetime(2000,4,1)).days
         days_2006_inversion = (negative_impact.index[17] - dt.datetime(2006,1,1)).days
```

Since there is no date for which the four indicators showed a detrimental impact following the inversion of 1998, it seems to be a false positive and will be excluded it from this calculation.

```
In [22]: time_delay = pd.DataFrame(index = ['1982', '1989', '2000-2001', '2006-2007'])
         time_delay['Days_Since_Inversion'] = (days_1982_inversion,
                                               days_1989_inversion,
                                               days_2000_inversion,
                                              days_2006_inversion)
```

```
In [23]: time_delay
```

```
Out[23]:            Days_Since_Inversion
         1982                         28
         1989                        396
         2000-2001                   334
         2006-2007                   790
```

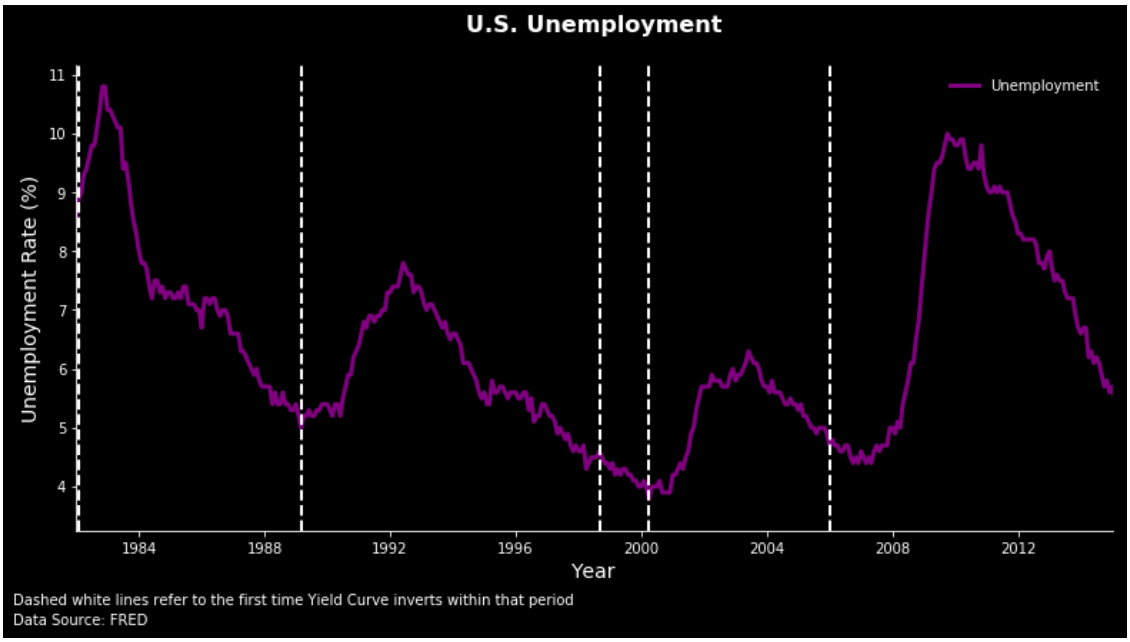
0.5 Visuals

Unemployment Rate

```
In [24]: plt.style.use('dark_background')
```

This changes the default style to one with a dark background.

In [25]:
```
fig, ax = plt.subplots(figsize = (13,6))

ax.plot(economic_indicators.index, economic_indicators.Unemployment_Rate ,
        color = 'purple', linewidth = 3.0)

ax.set_title("U.S. Unemployment\n", fontsize = 16, fontweight = "bold")
ax.set_ylabel("Unemployment Rate (%)", fontsize = 14,)
ax.set_xlabel("Year", fontsize = 14,)

ax.set_xlim(dt.datetime(1982,1,1), dt.datetime(2015,1,1))

ax.spines["right"].set_visible(False)
ax.spines["top"].set_visible(False)

ax.axvline(x= dt.datetime(1982,2,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)
ax.axvline(x= dt.datetime(1989,3,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)
ax.axvline(x= dt.datetime(1998,9,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)
ax.axvline(x= dt.datetime(2000,4,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)
ax.axvline(x= dt.datetime(2006,1,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)

ax.legend(["Unemployment"],frameon=False)

ax.text(dt.datetime(1980,1,1), 1.65, "Data Source: FRED", fontsize = 10)
ax.text(dt.datetime(1980,1,1), 2,
"Dashed white lines refer to the first time Yield Curve inverts within that period",
        fontsize = 10)

plt.savefig("unemployment_rate.png", bbox_inches = "tight", dip = 3000)

plt.show()
```

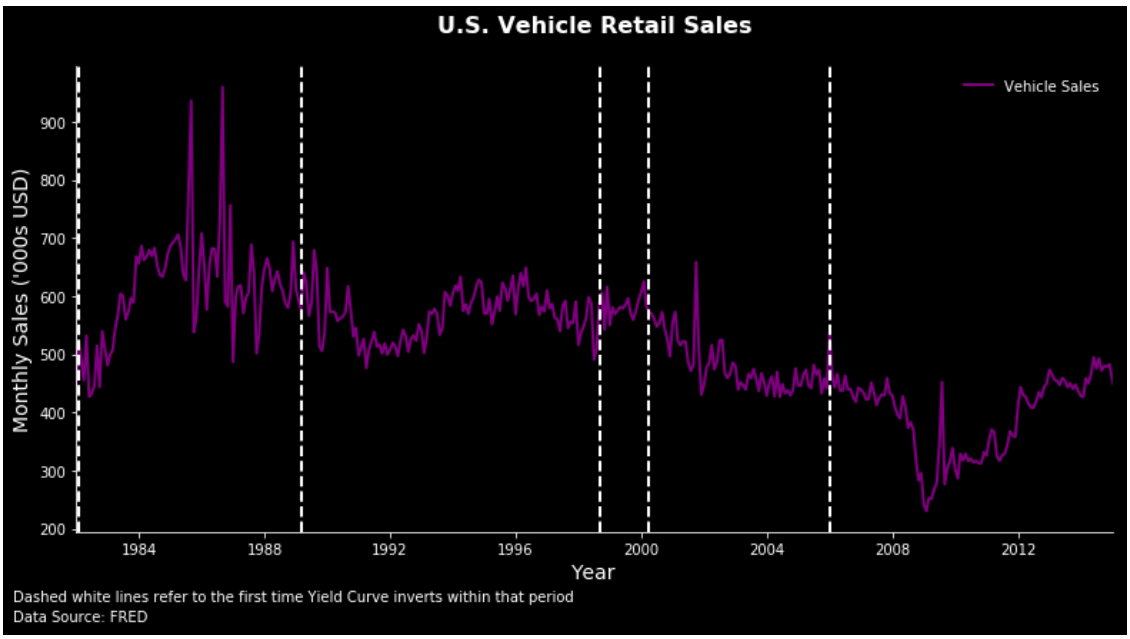


Above we see what was expected: following each inversion, except for 1998's, the unemployment rate spiked up.

Vehicle Sales

```
In [26]: fig, ax = plt.subplots(figsize = (13,6))

         ax.plot(economic_indicators.index, economic_indicators.Vehicle_Sales ,
                 color = 'purple', linewidth = 2.0)

         ax.set_title("U.S. Vehicle Retail Sales\n", fontsize = 16, fontweight = "bold")
         ax.set_ylabel("Monthly Sales ('000s USD)", fontsize = 14,)
         ax.set_xlabel("Year", fontsize = 14,)

         ax.set_xlim(dt.datetime(1982,1,1), dt.datetime(2015,1,1))

         ax.spines["right"].set_visible(False)
         ax.spines["top"].set_visible(False)

         ax.axvline(x= dt.datetime(1982,2,1), color='white', label='Inverts',
                    linestyle='--', linewidth=2)
         ax.axvline(x= dt.datetime(1989,3,1), color='white', label='Inverts',
                    linestyle='--', linewidth=2)
         ax.axvline(x= dt.datetime(1998,9,1), color='white', label='Inverts',
                    linestyle='--', linewidth=2)
         ax.axvline(x= dt.datetime(2000,4,1), color='white', label='Inverts',
                    linestyle='--', linewidth=2)
         ax.axvline(x= dt.datetime(2006,1,1), color='white', label='Inverts',
                    linestyle='--', linewidth=2)
```

```
ax.legend(["Vehicle Sales"],frameon=False)

ax.text(dt.datetime(1980,1,1), 40, "Data Source: FRED", fontsize = 10)
ax.text(dt.datetime(1980,1,1), 75,
"Dashed white lines refer to the first time Yield Curve inverts within that period",
        fontsize = 10)

plt.savefig("vehicle_sales.png", bbox_inches = "tight", dip = 3000)

plt.show()
```

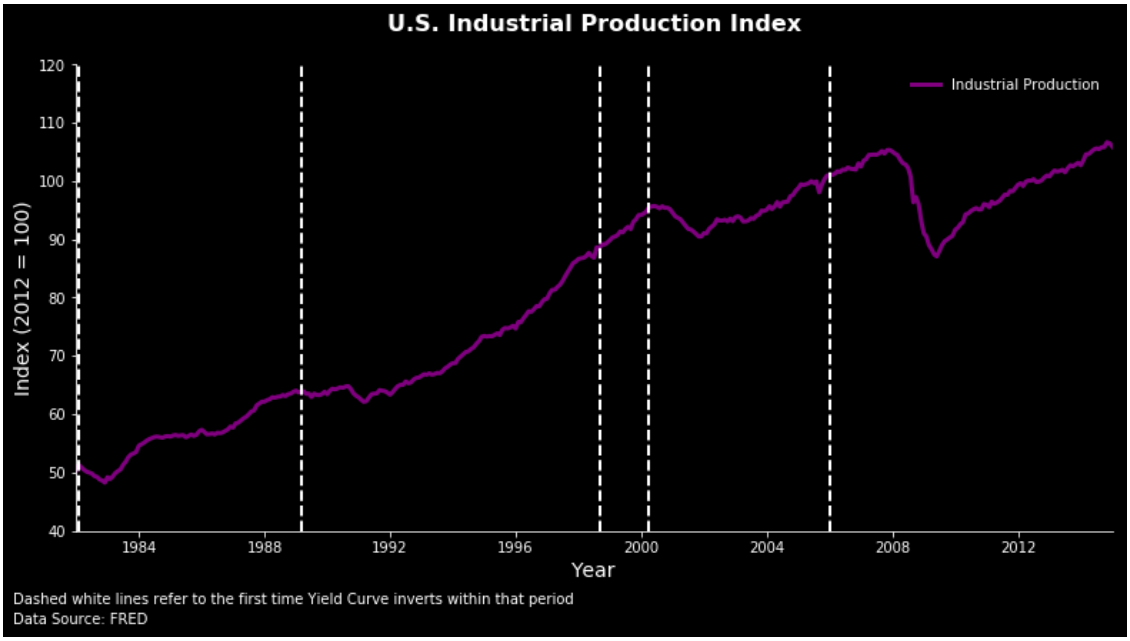


Although the indicator is very volative, above we can see that at least for the 1989, 2000-2001, and 2006-2007 inversions vehicle sales dropped. As discussed before, 1998 seems to be an exception and for a reason unknown to me vehicle sales did not extensively drop after the 1982 inversion.

Industrial Production

```
In [27]: fig, ax = plt.subplots(figsize = (13,6))

         ax.plot(economic_indicators.index, economic_indicators.Industrial_Production ,
                 color = 'purple', linewidth = 3.0)

         ax.set_title("U.S. Industrial Production Index\n", fontsize = 16, fontweight = "bold"
         ax.set_ylabel("Index (2012 = 100)", fontsize = 14,)
         ax.set_xlabel("Year", fontsize = 14,)

         ax.set_xlim(dt.datetime(1982,1,1), dt.datetime(2015,1,1))
```

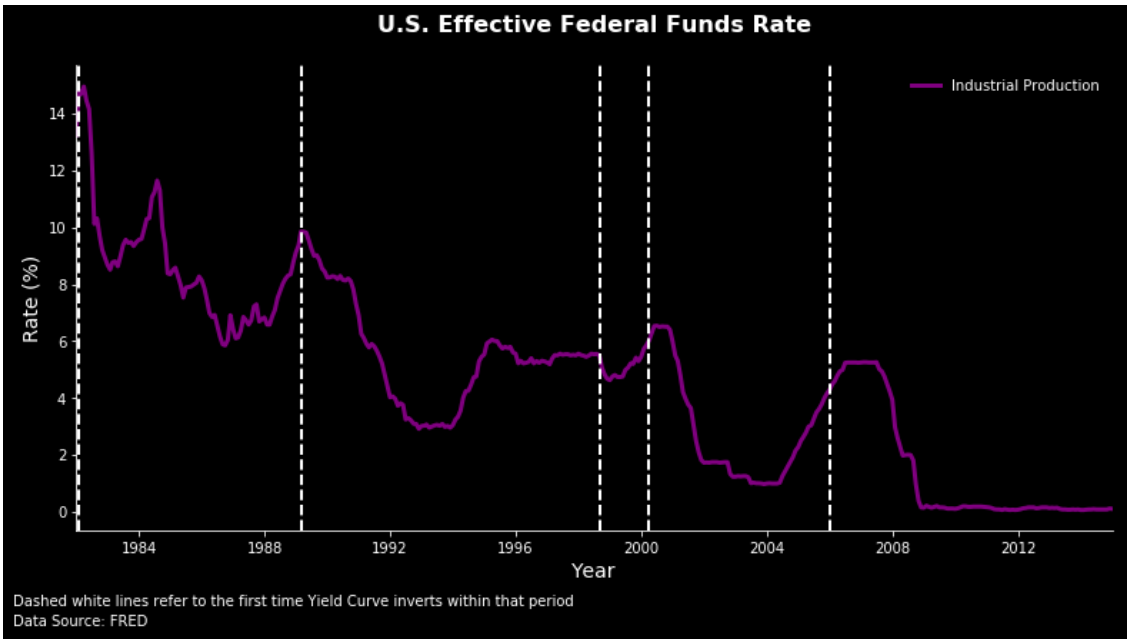
```
ax.set_ylim(40, 120)

ax.spines["right"].set_visible(False)
ax.spines["top"].set_visible(False)

ax.axvline(x= dt.datetime(1982,2,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)
ax.axvline(x= dt.datetime(1989,3,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)
ax.axvline(x= dt.datetime(1998,9,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)
ax.axvline(x= dt.datetime(2000,4,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)
ax.axvline(x= dt.datetime(2006,1,1), color='white', label='Inverts',
           linestyle='--', linewidth=2)

ax.legend(["Industrial Production"],frameon=False)

ax.text(dt.datetime(1980,1,1), 24, "Data Source: FRED", fontsize = 10)
ax.text(dt.datetime(1980,1,1), 27.5,
"Dashed white lines refer to the first time Yield Curve inverts within that period",
        fontsize = 10)

plt.savefig("industrial_production.png", bbox_inches = "tight", dip = 3000)

plt.show()
```



Above we see that the Industrial Production Index drops, even if slightly, after every inversion except for the one in 1998. This is what was expected to be seen given that the industrial sector slows down when the economy is performing poorly.

Fed Funds Rate

```
In [28]: fig, ax = plt.subplots(figsize = (13,6))

         ax.plot(economic_indicators.index, economic_indicators.Fed_Funds ,
                 color = 'purple', linewidth = 3.0)

         ax.set_title("U.S. Effective Federal Funds Rate\n", fontsize = 16, fontweight = "bold"
         ax.set_ylabel("Rate (%)", fontsize = 14,)
         ax.set_xlabel("Year", fontsize = 14,)

         ax.set_xlim(dt.datetime(1982,1,1), dt.datetime(2015,1,1))

         ax.spines["right"].set_visible(False)
         ax.spines["top"].set_visible(False)

         ax.axvline(x= dt.datetime(1982,2,1), color='white', label='Inverts',
                    linestyle='--', linewidth=2)
         ax.axvline(x= dt.datetime(1989,3,1), color='white', label='Inverts',
                    linestyle='--', linewidth=2)
         ax.axvline(x= dt.datetime(1998,9,1), color='white', label='Inverts',
                    linestyle='--', linewidth=2)
         ax.axvline(x= dt.datetime(2000,4,1), color='white', label='Inverts',
                    linestyle='--', linewidth=2)
         ax.axvline(x= dt.datetime(2006,1,1), color='white', label='Inverts',
                    linestyle='--', linewidth=2)

         ax.legend(["Industrial Production"],frameon=False)

         ax.text(dt.datetime(1980,1,1), -4, "Data Source: FRED", fontsize = 10)
         ax.text(dt.datetime(1980,1,1), -3.3,
         "Dashed white lines refer to the first time Yield Curve inverts within that period",
                 fontsize = 10)

         plt.savefig("fed_funds.png", bbox_inches = "tight", dip = 3000)

         plt.show()
```

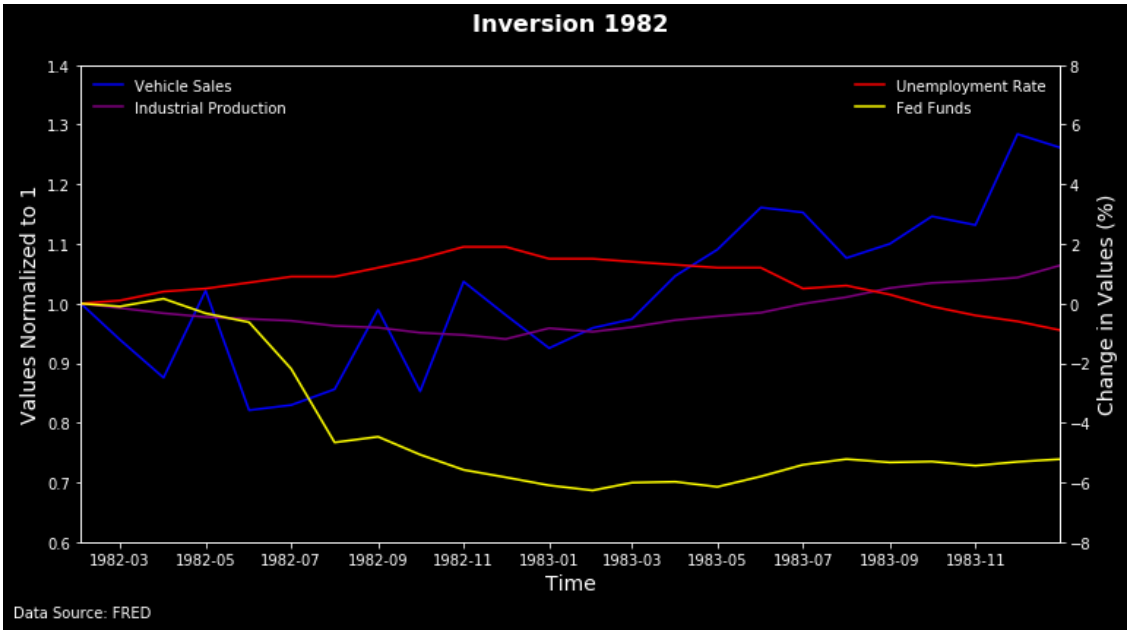


Above we can see that the Effective Federal Funds Rate drops after the inversions, even the 1998 in this case, which is what was bound to happen. The Federal Reserve performs Open Market Operations to lower this rate so that more credit is available, thus, stimulating the economy.

1982 Inversion

```
In [29]: fig, ax1 = plt.subplots(figsize=(12,6))

         ax1.plot(inversion_1982.index, inversion_1982['Vehicle_Sales'],
                 color = 'blue', label = 'Vehicle Sales', alpha = 1)
         ax1.plot(inversion_1982.index, inversion_1982['Industrial_Production'],
                 color = 'purple', label = 'Industrial Production', alpha = 1)

         ax1.set_ylabel("Values Normalized to 1", fontsize = 14,)
         ax1.legend(frameon=False, loc = 'upper left')
         ax1.set_xlabel("Time", fontsize = 14,)
         ax1.set_ylim(0.6,1.4)

         ax2 = ax1.twinx()

         ax2.plot(inversion_1982.index, inversion_1982['Unemployment_Rate'],
                 color = 'red', label = 'Unemployment Rate', alpha = 1)
         ax2.plot(inversion_1982.index, inversion_1982['Fed_Funds'],
                 color = 'yellow', label = 'Fed Funds', alpha = 1)

         ax2.set_title('Inversion 1982\n', fontsize = 16, fontweight = "bold")
         ax2.set_ylabel("Change in Values (%)", fontsize = 14,)
         ax2.set_xlim(dt.datetime(1982,2,1), dt.datetime(1983, 12, 31))
         ax2.set_ylim(-8,8)
```

```
ax2.legend(frameon=False)

ax1.text(dt.datetime(1981,12,15), 0.475, "Data Source: FRED", fontsize = 10)

plt.savefig("inversion_1982.png", bbox_inches = "tight", dip = 3000)

plt.show()
```

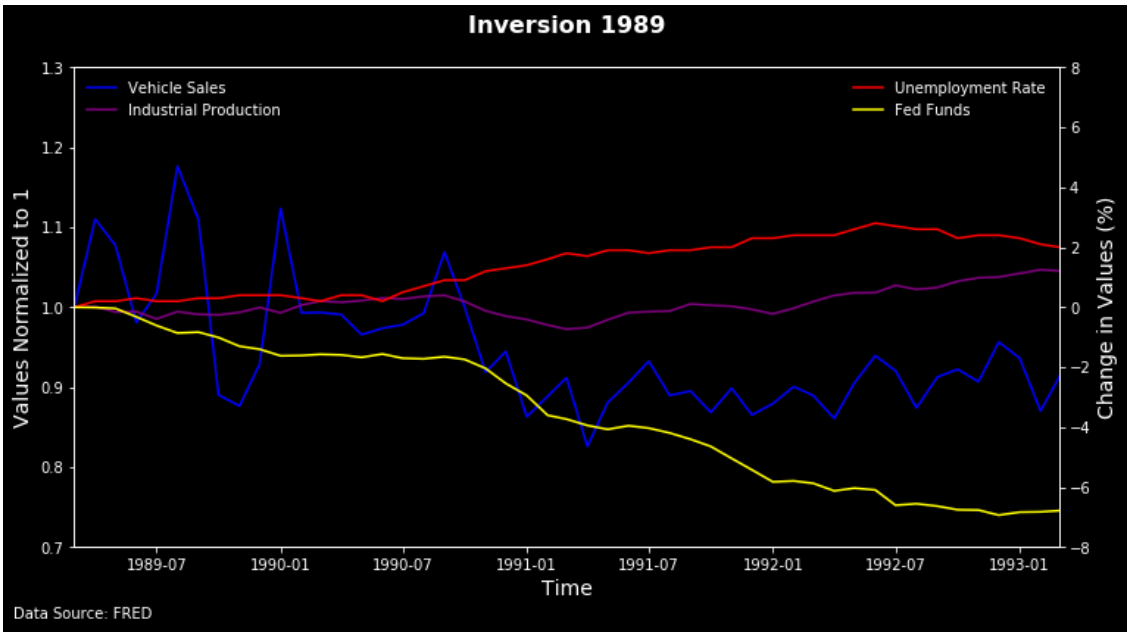


As shown, the 1982 inversion was followed by a period of moderate economic setbacks. In particular, we see a big drop in the Fed Funds Rate and a normal increase in the Unemployment Rate. However, Vehicle Sales actually pick up, something we also saw in the U.S. Vehicle Sales plot, and Industrial Production only drops slightly before eventually rising.

1989 Inversion

```
In [30]: fig, ax1 = plt.subplots(figsize=(12,6))

         ax1.plot(inversion_1989.index, inversion_1989['Vehicle_Sales'],
                  color = 'blue', label = 'Vehicle Sales', alpha = 1)
         ax1.plot(inversion_1989.index, inversion_1989['Industrial_Production'],
                  color = 'purple', label = 'Industrial Production', alpha = 1)

         ax1.set_ylabel("Values Normalized to 1", fontsize = 14,)
         ax1.legend(frameon=False, loc = 'upper left')
         ax1.set_xlabel("Time", fontsize = 14,)
         ax1.set_ylim(0.7,1.3)

         ax2 = ax1.twinx()
```

```
ax2.plot(inversion_1989.index, inversion_1989['Unemployment_Rate'],
        color = 'red', label = 'Unemployment Rate', alpha = 1)
ax2.plot(inversion_1989.index, inversion_1989['Fed_Funds'],
        color = 'yellow', label = 'Fed Funds', alpha = 1)

ax2.set_title('Inversion 1989\n', fontsize = 16, fontweight = "bold")
ax2.set_ylabel("Change in Values (%)", fontsize = 14,)
ax2.set_xlim(dt.datetime(1989,3,1), dt.datetime(1993, 3, 1))
ax2.set_ylim(-8,8)
ax2.legend(frameon=False)

ax1.text(dt.datetime(1988,12,1), 0.611, "Data Source: FRED", fontsize = 10)

plt.savefig("inversion_1989.png", bbox_inches = "tight", dip = 3000)

plt.show()
```

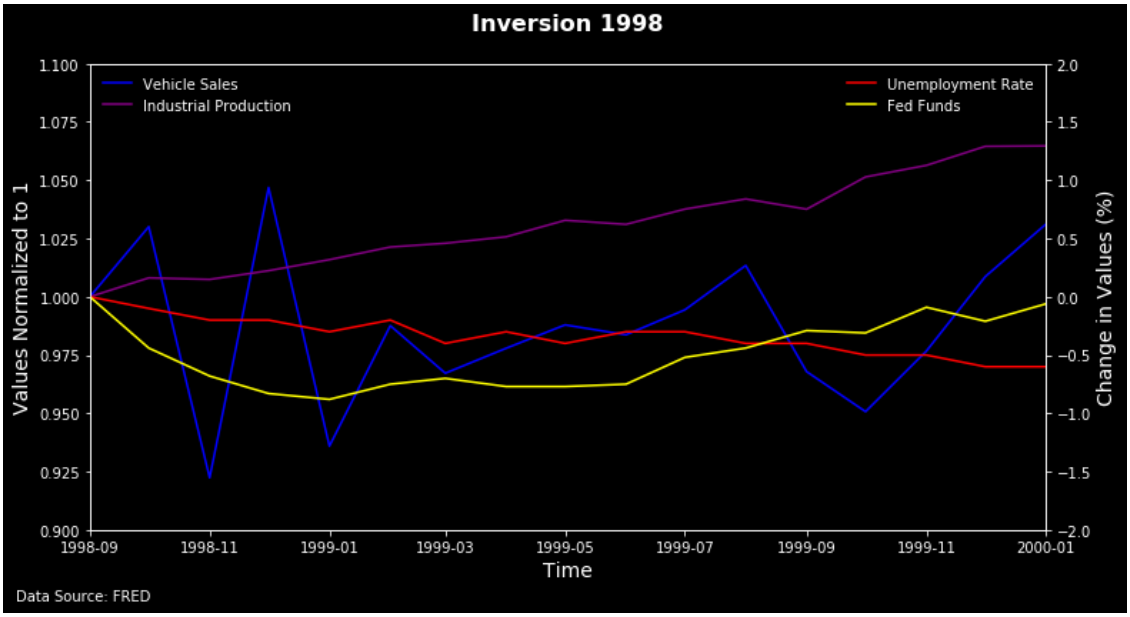


As showed by the graph above, the 1989 inversion was followed by a slight recession. There is a homogenous decrease in Vehicle Sales, Industrial Production, and the Fed Funds, while Unemployment rose.

1998 Inversion

```
In [31]: fig, ax1 = plt.subplots(figsize=(12,6))

        ax1.plot(inversion_1998.index, inversion_1998['Vehicle_Sales'],
                color = 'blue', label = 'Vehicle Sales', alpha = 1)
        ax1.plot(inversion_1998.index, inversion_1998['Industrial_Production'],
                color = 'purple', label = 'Industrial Production', alpha = 1)
```

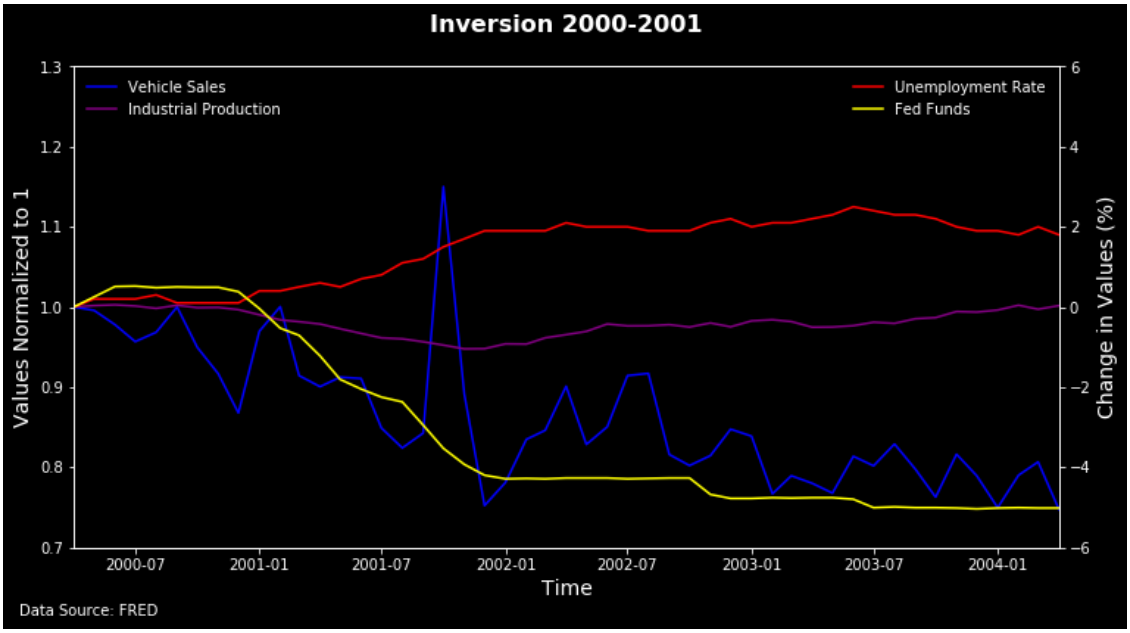
```
ax1.set_ylabel("Values Normalized to 1", fontsize = 14,)
ax1.legend(frameon=False, loc = 'upper left')
ax1.set_xlabel("Time", fontsize = 14,)
ax1.set_ylim(.9,1.1)

ax2 = ax1.twinx()

ax2.plot(inversion_1998.index, inversion_1998['Unemployment_Rate'],
        color = 'red', label = 'Unemployment Rate', alpha = 1)
ax2.plot(inversion_1998.index, inversion_1998['Fed_Funds'],
        color = 'yellow', label = 'Fed Funds', alpha = 1)

ax2.set_title('Inversion 1998\n', fontsize = 16, fontweight = "bold")
ax2.set_ylabel("Change in Values (%)", fontsize = 14,)
ax2.set_xlim(dt.datetime(1998,9,1), dt.datetime(2000, 1, 1))
ax2.set_ylim(-2,2)
ax2.legend(frameon=False)

ax1.text(dt.datetime(1998,7,25), .87, "Data Source: FRED", fontsize = 10)

plt.savefig("inversion_1998.png", bbox_inches = "tight", dip = 3000)

plt.show()
```



As we can see above, the inversion in 1998 did not have any significant effect in the economy. This is in line with what the plots of the individual economic indicators showed. The only indicator that showed a small sign of an economic decline was the Fed Funds, but even this was minimal (less than a -1% change).

2000-2001 Inversion

```
In [32]: fig, ax1 = plt.subplots(figsize=(12,6))

         ax1.plot(inversion_2000.index, inversion_2000['Vehicle_Sales'],
                 color = 'blue', label = 'Vehicle Sales', alpha = 1)
         ax1.plot(inversion_2000.index, inversion_2000['Industrial_Production'],
                 color = 'purple', label = 'Industrial Production', alpha = 1)

         ax1.set_ylabel("Values Normalized to 1", fontsize = 14,)
         ax1.legend(frameon=False, loc = 'upper left')
         ax1.set_xlabel("Time", fontsize = 14,)
         ax1.set_ylim(.7,1.3)

         ax2 = ax1.twinx()

         ax2.plot(inversion_2000.index, inversion_2000['Unemployment_Rate'],
                 color = 'red', label = 'Unemployment Rate', alpha = 1)
         ax2.plot(inversion_2000.index, inversion_2000['Fed_Funds'],
                 color = 'yellow', label = 'Fed Funds', alpha = 1)

         ax2.set_title('Inversion 2000-2001\n', fontsize = 16, fontweight = "bold")
         ax2.set_ylabel("Change in Values (%)", fontsize = 14,)
         ax2.set_xlim(dt.datetime(2000,4,1), dt.datetime(2004, 4, 1))
         ax2.set_ylim(-6,6)
         ax2.legend(frameon=False)

         ax1.text(dt.datetime(2000,1,10), .615, "Data Source: FRED", fontsize = 10)

         plt.savefig("inversion_2000.png", bbox_inches = "tight", dip = 3000)

         plt.show()
```

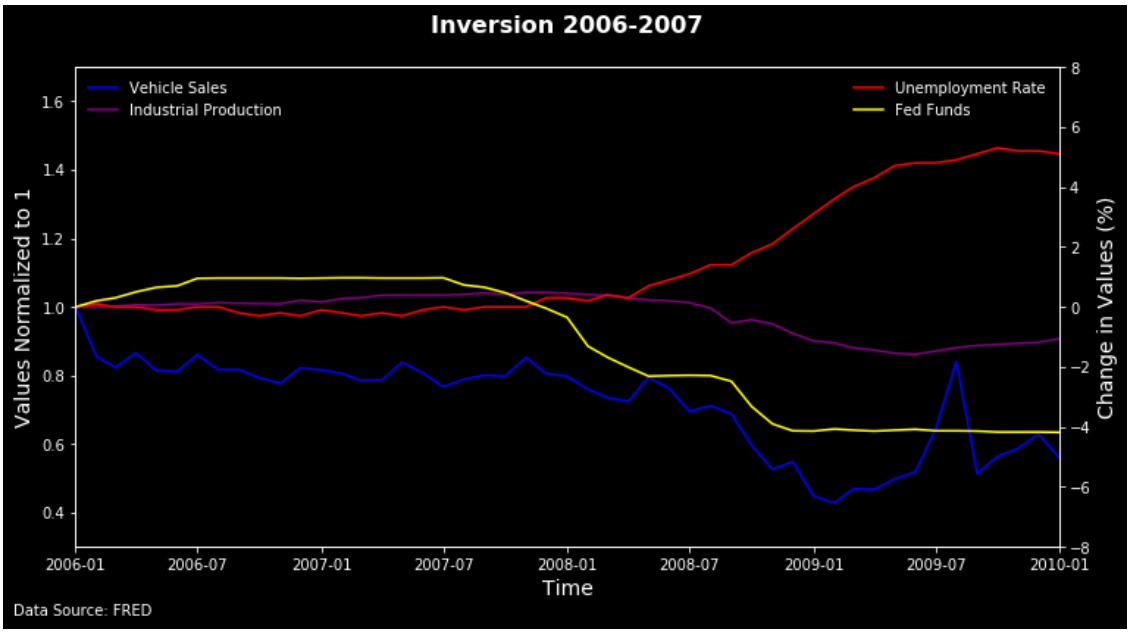


The inversion of 2000-2001, as shown above, was followed by a moderate period of economic decline. This period is commonly referred to as the Dotcom bust which was preceded by the Dotcom bubble. The same three indicators which are expected to drop during a recession, dropped and the Unemployment Rate rose due to a large amount of layoffs.

2006-2007 Inversion

```
In [33]: fig, ax1 = plt.subplots(figsize=(12,6))

         ax1.plot(inversion_2006.index, inversion_2006['Vehicle_Sales'],
                 color = 'blue', label = 'Vehicle Sales', alpha = 1)
         ax1.plot(inversion_2006.index, inversion_2006['Industrial_Production'],
                 color = 'purple', label = 'Industrial Production', alpha = 1)

         ax1.set_ylabel("Values Normalized to 1", fontsize = 14,)
         ax1.legend(frameon=False, loc = 'upper left')
         ax1.set_xlabel("Time", fontsize = 14,)
         ax1.set_ylim(0.3,1.7)

         ax2 = ax1.twinx()

         ax2.plot(inversion_2006.index, inversion_2006['Unemployment_Rate'],
                 color = 'red', label = 'Unemployment Rate', alpha = 1)
         ax2.plot(inversion_2006.index, inversion_2006['Fed_Funds'],
                 color = 'yellow', label = 'Fed Funds', alpha = 1)

         ax2.set_title('Inversion 2006-2007\n', fontsize = 16, fontweight = "bold")
         ax2.set_ylabel("Change in Values (%)", fontsize = 14,)
         ax2.set_xlim(dt.datetime(2006,1,1), dt.datetime(2010, 1, 1))
```

```
ax2.set_ylim(-8,8)
ax2.legend(frameon=False)

ax1.text(dt.datetime(2005,10,1), .1, "Data Source: FRED", fontsize = 10)

plt.savefig("inversion_2006.png", bbox_inches = "tight", dip = 3000)

plt.show()
```



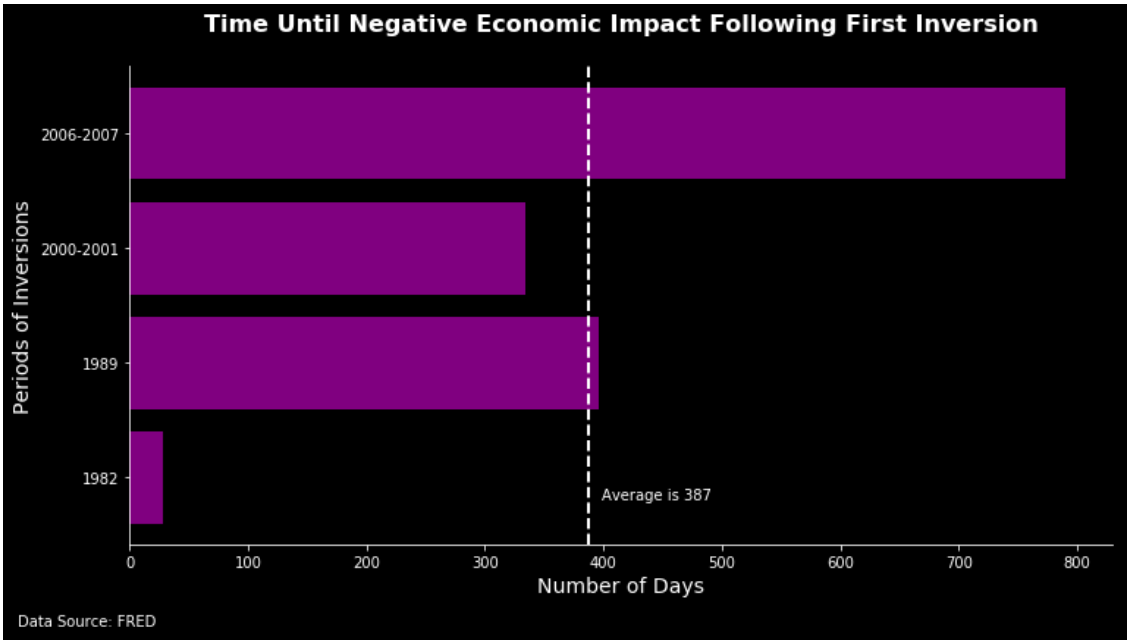
As shown above, the inversion in 2006-2007 was followed by one of the most drastic economic declines in U.S. history. This explains why the Unemployment Rate skyrocketed at such a steep angle and the Fed Funds Rate, Vehicle Sales, and Industrial Production steeply fell. Nothing less was expected of what became known as The Great Recession.

Time Delay

Now that the relationship between the Yield Curve and the U.S. economy has been established, it would be useful to determine how long it takes from the time the Curve inverts until the economy is affected. To do this, I will create a bar chart with the time it took all four economic indicator to experience a decline (or increase if Unemployment Rate) in growth after the first time an inversion in the Yield Curve occured for four out the five inversions.

```
In [35]: fig, ax = plt.subplots(figsize=(12,6))

         avg = time_delay.Days_Since_Inversion.mean()

         ax.barh(time_delay.index, time_delay.Days_Since_Inversion, color = 'purple')

         ax.set_title("Time Until Negative Economic Impact Following First Inversion\n",
                      fontsize = '16', fontweight = 'bold')
```

```
ax.set_ylabel("Periods of Inversions", fontsize = '14')
ax.set_xlabel("Number of Days", fontsize = '14')

ax.text(-95, -1.3, "Data Source: FRED", fontsize = 10)

average = "Average is " + str(round(avg))
ax.text(avg + 12, -.2, average, horizontalalignment='left')

ax.spines["right"].set_visible(False)
ax.spines["top"].set_visible(False)

ax.axvline(x=avg, color='white', linestyle='--', linewidth=2)

plt.savefig("time_delay.png", bbox_inches = "tight", dip = 3000)

plt.show()
```



Conclusion

From looking at all the data there are three main takeaways. They are as follows:

1. The Yield Curve can indeed serve as a predictor of future economic crises. As we saw four out of five times, the U.S. economy was faced with an economic crisis after the inversions.
2. 1998's Yield Curve inversion was not followed by a recession. Therefore, the relationship should nevertheless be taken with a grain of salt.
3. From the first time the Curve inverts, it takes 387 days on average for the Unemployment Rate, Vehicle Sales, Industrial Production, and the Effective Funds Rate to all simultaneously indicate an economic decline.

With this I conclude and thank Professor Waugh for the guidance on this project as well as FRED for publishing the data used.